

924. *Reaction of Some Substituted Methylthiomethyl-benzenes and -naphthalenes with Methyl Iodide.*

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The preparation of some substituted dialkyl-benzyl- and -naphthyl-methylsulphonium salts for antitubercular screening is described. Reaction of substituted methylthiomethyl-benzenes, -naphthalenes, and -1,3-benzodioxans with methyl iodide has been shown to give rise to both the expected sulphonium salts and anomalous products. The effect of substituents in the benzene ring on this reaction has been investigated.

WHILE ethyl thiol-esters and compounds containing a potential ethanethiol group have been shown to possess tuberculostatic activity *in vivo*,¹ simple sulphonium salts do not appear to have received much attention from this viewpoint. As part of an antitubercular screening programme, a series of such salts (I) together with some methylthiomethyl-benzenes and -naphthalenes and the corresponding sulphones has now been prepared and has been tested for tuberculostatic activity in mice by Rees and Robson's intracorneal infection method.²

Although alkyl aryl sulphides (II; $n = 0$) (including the naphthyl compounds) react only slowly with dimethyl sulphate to give sulphonium salts (I; $n = 0$) according to route (1),^{3,4} no special difficulties have been reported in the preparation of sulphonium salts with two or three methylene groups in the side-chain.^{5,6} Diverse reports occur, however, relating to the ease of preparation of sulphonium salts containing only one side-chain methylene (I; $n = 1$). Thus Ströholm's claim⁷ to have obtained sulphonium salts by reaction of benzyl ethyl and benzyl propyl sulphide with methyl iodide conflicts with the findings of Lewis and Archer⁸ who observed that benzyl methyl sulphide and methyl

¹ Kushner, Delaliam, Bach, Centola, Sanjurjo, and Williams, *J. Amer. Chem. Soc.*, 1955, **77**, 1152; Rist, Grumbach, and Libermann, *Amer. Rev. Tuberc.*, 1959, **79**, 1; B.P. 789,985.

² Rees and Robson, *Brit. J. Pharmacol.*, 1950, **5**, 77.

³ Baker and Mofitt, *J.*, 1930, 1722.

⁴ Belov and Finkel'shtein, *J. Gen. Chem. (U.S.S.R.)*, 1947, **17**, 741; Mamalis, Ph.D. Thesis, London, 1953.

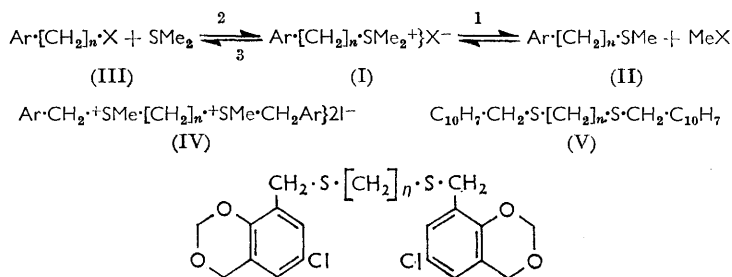
⁵ Hughes, Ingold, and Maw, *J.*, 1948, 2072; von Braun, Teuffert, and Weissbach, *Annalen*, 1929, **472**, 121.

⁶ Enner, Borovicka, and Protiva, *Coll. Czech. Chem. Comm.*, 1953, **18**, 270.

⁷ Ströholm, *Ber.*, 1900, **33**, 834.

⁸ Lewis and Archer, *J. Amer. Chem. Soc.*, 1951, **73**, 2109.

iodide gave only trimethylsulphonium iodide and a lachrymatory oil, probably benzyl iodide. These products would arise if the initial product (I; Ar = Ph, $n = 1$) decomposed according to route (3) to give dimethyl sulphide which, on reaction with excess of methyl iodide, would give sparingly soluble trimethylsulphonium iodide.



In view of these facts and since the few dialkylbenzylsulphonium salts described have been prepared from dialkyl sulphides and benzyl bromides (III) according to route (2),^{3,8,9} this method was selected for the preparation of the required compounds (I; $n = 1$). Substituted benzyl bromides and 1- and 2-bromomethylnaphthalene reacted smoothly at room temperature with dimethyl or diethyl sulphide in the absence of solvent, to give sulphonium bromides which were rather unstable to heat. Treatment of the same bromomethyl derivatives with sodium methyl sulphide, or methylation of the thiols obtained by alkaline hydrolysis of arylmethylthiuronium salts, gave methylthio-derivatives (II; $n = 1$) from which the corresponding sulphones were obtained by oxidation.

$\alpha\omega$ -Dibromoalkanes did not react with 1-methylthiomethylnaphthalene or with 6-chloro-8-mercaptomethyl-1,3-benzodioxane at room temperature and therefore we attempted the preparation of polymethylenebisulphonium salts (IV) by reaction of the sulphides (V and VI) with methyl iodide. Although reaction readily took place, the expected salts (IV) were not obtained, analyses of the products indicating the derived alkylenebisdimethylsulphonium iodides. From the mother-liquors were isolated, in some cases, 1- and 2-iodomethylnaphthalene and 6-chloro-8-iodomethyl-1,3-benzodioxane from (V) and (VI), respectively.

The formation of these anomalous products paralleled Lewis and Archer's observations and this type of reaction has been noted by other workers.¹⁰ For instance, dibenzyl sulphide with methyl iodide yielded trimethylsulphonium iodide and benzyl iodide;¹¹ and in the reaction of methyl 1-phenylethyl sulphide and methyl bromide the yield of sulphonium salt decreased (and the yield of trimethylsulphonium bromide correspondingly increased) with longer reaction and use of more methyl bromide.¹² We therefore studied the extent to which reaction is anomalous when methyl iodide reacts with substituted methylthio-methyl-benzenes and -naphthalenes. Treating benzyl methyl sulphide with a large excess of methyl iodide at room temperature for 24 hours gave only trimethylsulphonium iodide and benzyl iodide. Methyl 4-methylbenzyl sulphide gave, under these conditions, a mixture of trimethylsulphonium iodide and dimethyl-4-methylbenzylsulphonium iodide: 4-chlorobenzyl methyl sulphide and methyl iodide yielded analogous products. Both 4-chloro- and 4-methyl-benzyl methyl sulphide with methyl bromide in nitromethane yielded only trimethylsulphonium bromide and the benzyl bromide. 1-Methylthiomethylnaphthalene with methyl iodide gave a mixture of sulphonium salts together with 1-iodomethylnaphthalene. Also, when benzyldimethyl- or dimethyl-4-methylbenzyl-sulphonium salts

⁹ Pollard and Robinson, *J.*, 1930, 1765; Challenger and Rawlings, *J.*, 1937, 868.

¹⁰ Cf. Ray and Levine, *J. Org. Chem.*, 1937, 2, 267.

¹¹ Schöller, *Ber.*, 1874, 7, 1274; Cahours, *Ann. Chim. Phys.*, 1877, 10, 21.

¹² Siegel and Gaefe, *J. Amer. Chem. Soc.*, 1953, 75, 4521.

were left in ethanol with a large excess of methyl iodide for several days, trimethylsulphonium iodide was isolated in over 90% yield. From the mother-liquors lachrymatory oils were obtained.

It was confirmed that, for benzyl, 4-methylbenzyl, 4-methoxybenzyl, and 4-chlorobenzyl methyl sulphide at room temperature, longer reaction or increased quantities of methyl iodide resulted in greater yields of trimethylsulphonium iodide. The ease of formation of this iodide followed the sequence $H > MeO > Me > Cl$, which does not follow the normal electronegative series. *E.g.*, the number of mols. of methyl iodide required for complete conversion in 24 hours were: (II, $n = 1$) Ar = benzyl, 3; 4-methoxybenzyl, 10; 4-methylbenzyl, 20; 4-chlorobenzyl, >20; or 2, 5, 15, and 20, respectively in 72 hr. None of the sulphides gave any pure trimethylsulphonium iodide after only 4 hours' reaction.

None of the compounds examined exhibited significant tuberculostatic effects.

EXPERIMENTAL

Sulphonium Bromides (I; $n = 1$, X = Br).—The benzyl bromide or naphthylmethyl bromide (3.0 g.) and the dialkyl sulphide (5—8 ml.) were left at room temperature in a closed flask for 2—3 days during which a solid or gum separated. Addition of dry ether gave the salt which was recrystallised, the time of heating being kept to a minimum. Yields were usually above 80%. 4-Methoxybenzyl chloride reacted similarly to the bromides, to give the sulphonium chloride. The compounds prepared are listed in Table 1.

TABLE I. *Substituted sulphonium salts* $Ar \cdot CH_2 \cdot SR_2^+ \} X^-$.

Subst. in Ar	R	Salt	M. p. (decomp.)	Formula	Found (%)			Reqd. (%)		
					C	H	N	C	H	N
<i>Benzyl compounds</i>										
H	Me	Bromide	99—99.5 ^{o ad}	$C_9H_{13}BrS \cdot 0.5H_2O$	44.6	5.6	—	44.6	5.8	—
"	Me	Picrate	135 ^h							
4-Me	Me	Bromide	109—110 ^{ad}	$C_{10}H_{16}BrS$	48.4	6.0	—	48.6	6.1	—
"	Me	Picrate	115—116 ^{be}	$C_{16}H_{17}N_3O_7S$	49.1	4.5	—	48.6	4.3	—
"	Et	Bromide	73—74.5 ^{ad}	$C_{15}H_{19}BrS$	52.1	7.1	—	52.4	7.0	—
"	Et	Picrate	117 ^{af}	$C_{18}H_{21}N_3O_7S \cdot C_2H_6O$	51.4	5.4	8.5	51.2	5.8	8.95
4-Cl	Me	Bromide	124 ^{ad}	$C_9H_{12}BrClS$	40.5	4.7	—	40.4	4.5	—
"	Et	Bromide	81—83 ^{ad}	$C_{11}H_{16}BrClS$	44.2	5.6	—	44.6	5.45	—
"	Et	Picrate	99 ^{ae}	$C_{17}H_{20}ClN_3O_7S$	45.5	4.2	9.0	45.7	4.5	9.4
4-MeO	Me	Chloride	93—95 ^{apf}							
"	Me	Picryl-sulphonate	129—130 ^{be}	$C_{16}H_{17}N_3O_{10}S_2$	40.3	3.6	9.0	40.4	3.6	8.85
2-NO ₂	Me	Bromide	98—99 ^{be}	$C_9H_{12}BrNO_2S \cdot 0.5H_2O$	37.65	4.9	4.85	37.6	4.6	4.9
3-NO ₂	Me	Bromide	137—138 ^{ce}	$C_9H_{12}BrNO_2S$	39.1	4.55	—	38.9	4.4	—
4-NO ₂	Me	Bromide	112—113 ^{be}	$C_9H_{12}BrNO_2S$	39.0	4.5	5.1	38.9	4.4	5.0
"	Et	Bromide	90—91 ^{ad}	$C_{11}H_{16}BrNO_2S$	43.4	5.3	—	43.1	5.25	—
"	Et	Picrate	105—106 ^{af}	$C_{17}H_{20}N_4O_9S$	44.3	4.6	11.9	44.7	4.4	12.25
<i>1-Naphthylmethyl series</i>										
H	Me	Bromide	137—138 ^{be}	$C_{13}H_{16}BrS$	55.5	5.6	—	55.2	5.3	—
"	Et	Bromide	114—115 ^{ad}	$C_{15}H_{19}BrS$	57.9	6.3	—	57.9	6.1	—
4-Br	Me	Bromide	133—134 ^{ad}	$C_{13}H_{14}Br_2S$	43.3	4.2	—	43.2	3.9	—
"	Et	Bromide	114—116 ^{ad}	$C_{15}H_{16}Br_2S$	46.1	4.4	—	46.2	4.6	—
<i>Various</i>										
2-Naphthyl-methyl	Me	Bromide	132—133 ^{be}	$C_{13}H_{16}BrS$	55.05	5.4	—	55.2	5.3	—
9-Phenan-thrylmethyl	Me	Chloride	135—136 ^{bd}	$C_{17}H_{17}ClS$	70.7	6.1	—	70.6	5.9	—
10-Phenan-thridinyl-methyl	Me	Chloride	158—160 ^{ad}	$C_{16}H_{16}ClNS, H_2O$	62.9	5.8	—	62.5	5.9	—

* Needles. ^b Prisms. ^c Leaflets. Recryst. from: ^a methanol-dry ether, ^e ethanol, ^f aq. ethanol, ^g ethyl acetate-methanol. ^h Lit., ³ m. p. 134°, ⁸ m. p. 134—136°. ⁱ Ethanol solvate. ^j Too deliquescent for analysis.

Substituted S-Benzyl- and S-Naphthylmethyl-thiouonium Salts.—The halogenomethyl derivative (0.1 mole) and thiourea (0.1 mole) were refluxed together in ethanol (150 ml.) for 2 hr.

Concentration and cooling resulted in separation of the thiuronium salts in excellent yield, sufficiently pure for conversion into the thiols. The *salts* were crystallised from ethanol for analysis and are listed in Table 2.

TABLE 2. *Thiuronium salts.* Ar·S·C(=NH)·NH₂·HX.

Ar	X	M. p.	Formula	Found (%)			Required (%)		
				C	H	N	C	H	N
4-Methylbenzyl	Br	162—164°	C ₉ H ₁₃ BrN ₂ S	41.2	5.2	—	41.45	5.0	—
4-Chlorobenzyl	Br	195—196	C ₈ H ₁₀ BrClN ₂ S	34.2	3.7	9.8	34.1	3.6	9.95
2-Nitrobenzyl	Br	189—190	C ₈ H ₁₀ BrN ₃ O ₂ S	32.7	3.6	14.6	32.9	3.5	14.4
3-Nitrobenzyl	Br	198—200	C ₈ H ₁₀ BrN ₃ O ₂ S	33.1	3.7	14.7	32.9	3.5	14.4
4-Nitrobenzyl	Br	202—203	C ₈ H ₁₀ BrN ₃ O ₂ S	33.2	3.4	14.2	32.9	3.5	14.4
1-Naphthylmethyl	Cl	239 ^a	C ₁₂ H ₁₈ ClN ₂ S	57.0	5.1	10.9	57.0	5.2	11.1
2-Naphthylmethyl	Br	184	C ₁₂ H ₁₈ BrN ₂ S	48.8	4.3	9.4	48.5	4.4	9.3
6-Chloro-1,3-benzodioxan-8-yl)methyl	Cl	235—236	C ₁₀ H ₁₂ Cl ₂ N ₂ O ₂ S	41.04	4.2	9.4	40.7	4.1	9.5
2-1'-Naphthylethyl	Br	190—191	C ₁₃ H ₁₅ BrN ₂ S	50.2	4.9	9.7	50.2	4.85	9.0

^a Bonner¹³ gives m. p. 233°.

2-1'-Naphthylethanethiol.—S-2-1'-Naphthylethylthiuronium bromide (8.0 g.) and aqueous 4N-sodium hydroxide (50 ml.) were heated on the steam-bath for 30 min., then cooled and acidified with concentrated hydrochloric acid. The *thiol* isolated by ether-extraction had b. p. 108°/0.1 mm. (3.8 g.) (Found: C, 76.3; H, 6.3. C₁₂H₁₅S requires C, 76.6; H, 6.45%). *6-Chloro-1,3-benzodioxan-8-ylmethanethiol*, similarly prepared, formed needles (from aqueous ethanol), m. p. 79° (Found: C, 49.7; H, 4.0; Cl, 16.7. C₉H₉ClO₂S requires C, 49.8; H, 4.2; Cl, 16.4%). All other thiols used in this work were prepared by the same method and had the properties described in the literature.

Benzyl Methyl Sulphide.—Toluene- ω -thiol (12.4 g), sodium hydroxide (6.0 g.), and water (70 ml.) were stirred and slowly treated with dimethyl sulphate (18.9 g.) with cooling to below 50°. After the addition was complete, the mixture was heated on the steam-bath for 30 min., and the product isolated with ether. The sulphide had b. p. 84—86°/12 mm. (10.1 g.) (lit.,⁸ b. p. 52—54°/2 mm.,¹⁴ b. p. 85°/5 mm.).

Methyl 4-methylbenzyl sulphide, similarly prepared, had b. p. 108—109°/18 mm. (Found: C, 71.4; H, 8.1. C₉H₁₂S requires C, 71.1; H, 7.95%). *Methyl 1-naphthylmethyl sulphide*, b. p. 165—170°/15 mm., formed pale yellow prisms, m. p. 49°, from light petroleum (b. p. 40—60°) (Found: C, 77.0; H, 6.7. C₁₂H₁₂S requires C, 76.6; H, 6.4%). *6-Chloro-1,3-benzodioxan-8-ylmethyl methyl sulphide*, needles [from light petroleum (b. p. 40—60°)], had m. p. 42—43° (Found: C, 51.4; H, 5.1. C₁₀H₁₁ClO₂S requires C, 52.0; H, 4.8%).

4-Methoxybenzyl Methyl Sulphide.—To sodium methyl sulphide (2.5 g.) in methanol (25 ml.) was added 4-methoxybenzyl bromide (7.25 g.) portionwise at room temperature. Next morning, water was added and the oil extracted into ether. Distillation gave the *product* (4.3 g.), b. p. 127°/14 mm. (Found: C, 64.5; H, 7.1. C₉H₁₂OS requires C, 64.4; H, 7.2%). Other *sulphides* prepared by this method are recorded in Table 3.

TABLE 3. *Sulphides, Ar·SMe.*

Ar	B. p./mm.	Formula	Found (%)		Reqd. (%)	
			C	H	C	H
4-t-Butylbenzyl	95—96°/0.15	C ₁₂ H ₁₈ S	74.1	9.3	74.3	9.4
4-Methyl-1-naphthylmethyl	141—142°/0.4	C ₁₃ H ₁₄ S	77.6	7.1	77.2	7.0
4-Bromo-1-naphthylmethyl	158—159°/0.15	C ₁₂ H ₁₁ BrS	53.4	4.0	53.8	4.15
1-Chloro-2-naphthylmethyl	121—122°/0.2	C ₁₂ H ₁₁ ClS	56.6	4.4	56.5	4.4
1-Bromo-2-naphthylmethyl	132—140°/0.2 ^a	C ₁₂ H ₁₁ BrS	53.9	4.3	53.8	4.15

^a M. p. 35°, leaflets from light petroleum (b. p. 40—60°).

Ethyl 1-Naphthylmethyl Sulphide.—1-Naphthylmethanethiol (4.8 g.; b. p. 112°/0.1 mm.) (Weinstein and Pierson¹⁵ give b. p. 142—143°/0.5 mm.), N-sodium hydroxide (55 ml.), ethanol (10 ml.), and ethyl iodide (5.5 ml.) were shaken for 2 hr. The oil which separated was extracted

¹³ Bonner, *J. Amer. Chem. Soc.*, 1948, **70**, 3508.

¹⁴ Večefa, Gasparič, and Jevček, *Chem. Listy*, 1958, **52**, 144.

¹⁵ Weinstein and Pierson, *J. Org. Chem.*, 1958, **23**, 554.

into ether, washed, and dried. Distillation gave the *product*, b. p. 120°/0.1 mm. (4.5 g.) (Found: C, 76.9; H, 7.0; S, 15.6. C₁₃H₁₄S requires C, 77.2; H, 7.0; S, 15.8%). 6-Chloro-1,3-benzodioxan-8-ylmethyl ethyl sulphide, prepared similarly, b. p. 122—124°/0.1 mm., formed needles, m. p. 19—20° (Found: C, 53.5; H, 5.2; S, 12.4. C₁₁H₁₃ClO₂S requires C, 53.9; H, 5.4; S, 13.1%).

TABLE 4. Sulphides, Ar·CH₂·S·[CH₂]_n·S·CH₂·Ar.

Ar	n	M. p.	Formula	Found (%)			Required (%)		
				C	H	S	C	H	S
1-Naphthyl	2	73—74 ^{o ad}	C ₂₄ H ₂₂ S ₂	76.6	5.7	17.6	76.8	5.9	17.2
"	3	57—58 ^{bd}	C ₂₅ H ₂₄ S ₂	77.7	6.6	15.7	77.3	6.2	16.4
"	5	Oil ^g							
2-Naphthyl	2	155—156 ^{af}	C ₂₄ H ₂₂ S ₂	77.1	6.0	17.1	76.8	5.9	17.2
"	3	79—80 ^{ae}	C ₂₅ H ₂₄ S ₂	76.9	6.4	16.8	77.3	6.2	16.4
"	5	99—100 ^{be}	C ₂₇ H ₂₈ S ₂	77.4	6.4	15.4	77.7	6.8	15.4
"	10	105—106 ^{be}	C ₃₂ H ₃₈ S ₂	79.3	8.4	12.7	78.9	7.8	13.1
6-Chloro-1,3-benzodioxan-8-yl	2	149—151 ^{cd}	C ₂₀ H ₂₀ Cl ₂ O ₄ S ₂	52.1	4.2	15.5 ^f	52.2	4.4	15.4 ^f
"	3	89—91 ^{be}	C ₂₁ H ₂₂ Cl ₂ O ₄ S ₂	53.6	4.8	14.3 ^f	53.3	4.7	15.0 ^f
"	4	126—130 ^{bd}	C ₂₂ H ₂₄ Cl ₂ O ₄ S ₂	53.9	4.5	14.6 ^f	54.1	4.9	14.5 ^f
"	5	101—102 ^{bd}	C ₂₃ H ₂₆ Cl ₂ O ₄ S ₂	55.4	5.0	14.5 ^f	55.2	5.2	14.2 ^f
"	10	112—114 ^{bf}	C ₂₈ H ₃₂ Cl ₂ O ₄ S ₂	58.5	6.1	11.4	58.8	6.3	11.2
1-Naphthylmethyl	10	44—45 ^{bd}	C ₂₄ H ₂₆ S ₂	78.9	8.0	12.8	79.3	8.2	12.4
Phenyl	10	28 ^{bd}	C ₂₄ H ₂₄ S ₂	74.9	8.7	16.4	74.5	8.9	16.6

^a Leaflets. ^b Needles. ^c Prisms. Recryst. from: ^d ethylacetate-light petroleum (b. p. 40—60°), ^e ethyl acetate, ^f ethanol-ethyl acetate. ^g Oil, used directly in reaction with methyl iodide. ^f Chlorine analysis.

Decamethylene-1,10-bis-(1-naphthylmethyl Sulphide).—1-Naphthylmethanethiol (3.0 g.) was added to a solution of sodium (0.4 g.) in ethanol (20 ml.), followed by 1,10-dibromodecane (3.3 g.); an exothermic reaction took place. After 2 hours' heating, water was added and the solid collected. Crystallisation from ethyl acetate gave needles of the *product*, m. p. 79° (4.1 g.) (Found: C, 78.4; H, 7.9; S, 12.8. C₃₂H₃₈S₂ requires C, 79.0; H, 7.8; S, 13.2%). In a similar manner, the *bis-sulphides* described in Table 4 were prepared.

Benzyl Methyl Sulphone.—Benzyl methyl sulphide (0.5 g.), acetic acid (5.0 ml.), and aqueous 30% hydrogen peroxide (1.0 ml.) were heated together on the steam-bath for 10 min. after which more peroxide (1.0 ml.) was added and heating continued for another 20 min. The solvents were removed and the residual solid was crystallised from ethyl acetate-light petroleum (b. p. 40—60°), giving needles, m. p. 124—125° (0.42 g.) (lit.,⁸ m. p. 125—127°) (Found: C, 56.2; H, 5.9. Calc. for C₈H₁₀O₂S: C, 52.5; H, 5.9%). Other *sulphones* prepared by the same route are described in Table 5.

TABLE 5. Sulphones, Ar·CH₂·SO₂·Me.

Ar	M. p.	Formula	Found (%)		Required (%)	
			C	H	C	H
<i>p</i> -Tolyl	129 ^{o ac}	C ₉ H ₁₂ O ₂ S	58.7	6.5	58.7	6.6
<i>p</i> -Chlorophenyl	120 ^{acf}	C ₈ H ₉ ClO ₂ S	47.4	4.7	46.9	4.4
<i>p</i> - <i>t</i> -Butylphenyl	116 ^{be}	C ₁₂ H ₁₈ O ₂ S	63.6	8.0	63.7	8.0
4-Methyl-1-naphthyl	151 ^{ae}	C ₁₃ H ₁₄ O ₂ S	66.2	6.1	66.6	6.0
1-Chloro-2-naphthyl	146 ^{ae}	C ₁₂ H ₁₁ ClO ₂ S	56.6	4.4	56.5	4.4
1-Bromo-2-naphthyl	132 ^{ad}	C ₁₂ H ₁₁ BrO ₂ S	48.2	3.8	48.2	3.7

^a Needles. ^b Leaflets. Recryst. from: ^c ethanol, ^d aqueous ethanol, ^e ethyl acetate-light petroleum (b. p. 40—60°). ^f Lit.,⁸ m. p. 120—122°.

Decamethylene-1,10-bis(benzyl sulphone) formed needles, m. p. 153—154°, from acetone (Found: C, 64.3; H, 7.8. C₂₄H₃₄O₄S₂ requires C, 64.0; H, 7.6%).

Reactions of Sulphides with Methyl Iodide.—*Ethylene-1,2-bis-(1-naphthylmethyl sulphide)*. The sulphide (1.2 g.) was treated in acetone (5 ml.) with methyl iodide (5 ml.) and left at 20° for 48 hr. during which solid separated (0.8 g.). Crystallisation from ethanol-ether gave *ethylene-1,2-bis(dimethylsulphonium iodide)* as leaflets (0.65 g.), m. p. 104° (Found: C, 18.0; H, 3.5. C₆H₁₆I₂S₂ requires C, 17.7; H, 4.0%).

Pentamethylene-1,5-bis-(1-naphthylmethyl sulphide). The sulphide (1.5 g.), acetone (5 ml.), and methyl iodide (5 ml.) gave, after 48 hr., pentamethylene-1,5-bis(dimethylsulphonium iodide)

which formed needles (from ethanol-ether) (1.0 g.), m. p. 173° (Found: C, 24.5; H, 5.8; I, 56.7. Calc. for $C_9H_{22}I_2S_2$: C, 24.2; H, 5.0; I, 56.8%) (lit.,¹⁶ m. p. 182—183°,¹⁷ m. p. 176—178°).

Decamethylene-1,10-bis-(1-naphthylmethyl sulphide). The sulphide (1.0 g.), acetone (5 ml.), and methyl iodide (2 ml.), when left together overnight, deposited solid which recrystallised from ethanol, to give decamethylene-1,10-bis(dimethylsulphonium iodide) as prisms (0.62 g.), m. p. 116—117° (Found: C, 33.1; H, 6.6; I, 48.6. Calc. for $C_{14}H_{32}I_2S_2$: C, 32.4; H, 6.2; I, 49.0%) (lit.,¹⁶ m. p. 119—120°). The acetone mother-liquors were diluted with ether and washed with water. After evaporation, the residual oil and solid were extracted with hot light petroleum (b. p. 60—80°), the extracts were evaporated, and the residual solid was crystallised twice from light petroleum (b. p. 40—60°), giving needles, m. p. 60—61° which darkened. Infrared absorption was consistent with the compound's being 1-iodomethyl-naphthalene (Found: C, 49.9; H, 4.1. $C_{11}H_9I$ requires C, 49.2; H, 3.4%). 1-Iodomethylnaphthalene has previously been described¹⁸ (no analytical results) as a pale yellow solid, rapidly becoming black, b. p. 125°/0.1 mm., and as an oil decomposing on attempted distillation.¹⁹ Heating this iodide with thiourea in ethanol for 2 hr. gave the *thiouronium iodide*, needles, m. p. 181—182° (Found: C, 41.0; H, 4.3. $C_{12}H_{13}IN_2S$ requires C, 41.8; H, 3.8%). In another experiment, the sulphide (1.0 g.), acetone (5 ml.), and methyl iodide (0.26 ml., 2 equivs.) were left for 24 hr. The only crystalline product isolated was decamethylene-1,10-bis(dimethylsulphonium iodide) (0.15 g.), m. p. 114°.

Decamethylene-1,10-bis-(2-naphthylmethyl sulphide). The sulphide (2.0 g.), acetone (5 ml.), and methyl iodide (2 ml.) were left together overnight. The deposited solid crystallised from ethanol and was identified as decamethylene-1,10-bis(dimethylsulphonium iodide) (1.9 g.), m. p. 115—116°. After evaporation, crystallisation of the residual solid from light petroleum (b. p. 60—80°) afforded 2-iodomethylnaphthalene (0.7 g.), m. p. 78° (Found: C, 49.0; H, 3.6; I, 47.2. $C_{11}H_9I$ requires C, 49.2; H, 3.4; I, 47.4%). Daub and Castle¹⁸ obtained this product as an unstable solid, m. p. 72—73.5°, for which no analytical results were given: our product was stable for several weeks at room temperature.

Decamethylene-1,10-bis-(6-chloro-1,3-benzodioxan-8-ylmethyl sulphide). The sulphide (1.0 g.), acetone (5 ml.), and methyl iodide (5 ml.) were warmed to bring about solution, then left overnight, and the solid was collected (1.0 g.; m. p. 108—110°). Evaporation of the filtrate yielded more solid (0.52 g.), m. p. 125—130°. Crystallisation of the first crop from ethanol gave decamethylene-1,10-bis(dimethylsulphonium iodide) (0.8 g.), m. p. 115—116°, while the second crop afforded needles of 6-chloro-8-iodomethyl-1,3-benzodioxan, m. p. 140—141°, from ethyl acetate (Found: C, 34.9; H, 2.6. $C_9H_8ClIO_2$ requires C, 34.8; H, 2.6%). The same iodomethyl compound was formed when 6-chloro-8-chloromethyl-1,3-benzodioxan (1.05 g.), sodium iodide (2.0 g.), and acetone (20 ml.) were heated under reflux for 2 hr.; it formed needles (from ethanol) (1.0 g.), m. p. and mixed 139—141°.

Decamethylene-1,10-bis(benzyl sulphide). The sulphide (1.0 g.) and methyl iodide (5.0 ml.) gave decamethylene-1,10-bis(dimethylsulphonium iodide) (1.2 g.), m. p. 113—114°, and benzyl iodide characterised as the *thiouronium iodide*, m. p. 139—140° (prisms from ethanol) (Found: C, 32.75; H, 4.0; N, 9.4. $C_8H_{11}IN_2S$ requires C, 32.6; H, 3.8; N, 9.5%), and as the thiouronium picrate, m. p. 187—188° (lit.,²⁰ m. p. 182—183°).

Benzyl Methyl Sulphide.—The sulphide (0.98 g.) and methyl iodide (6 ml.) were mixed at room temperature. Solid began to separate after 25 min., and after 24 hr. was collected and washed with ether [1.43 g.; m. p. 196—200° (decomp.)]. Trimethylsulphonium iodide formed needles (from ethanol), m. p. 209—210° (decomp.) (Found: C, 17.9; H, 4.4. Calc. for C_3H_9IS : C, 17.6; H, 4.4%). Evaporation of the filtrates gave a red oil crystallising at ca. 5° as prismatic needles (0.94 g.) (Lieben²¹ gives m. p. 25° for benzyl iodide). The oil, when heated with thiourea (0.33 g.) in ethanol (20 ml.) for 2 hr., afforded S-benzylthiouronium iodide (1.0 g.), m. p. 139—140° not depressed on admixture with the sample obtained in the previous experiment.

Reaction of Benzyltrimethylsulphonium Bromide with Methyl Iodide.—A mixture of the

¹⁶ Walker, *J.*, 1950, 193.

¹⁷ Protiva, Jilek, and Exner, *Chem. Listy*, 1953, 47, 580.

¹⁸ Daub and Castle, *J. Org. Chem.*, 1954, 19, 1571.

¹⁹ Craniadès and Rumpf, *Bull. Soc. chim. France*, 1952, 1063.

²⁰ Werner, *J.*, 1890, 57, 285.

²¹ Lieben, *Jahresber. Fortschr. Chem.*, 1869, 425.

sulphonium bromide (0.5 g.), methyl iodide (5 ml.), and ethanol (5 ml.) was left for 6 days. The solid was collected and washed with ether, giving trimethylsulphonium iodide (0.40 g.), m. p. 208—210° (decomp.) (Found: C, 17.8; H, 4.6%). Evaporation of the mother-liquors afforded a lachrymatory red oil (0.53 g.).

Reactions of Methyl 4-Methylbenzyl Sulphide.—(a) A mixture of the sulphide (1.0 g.) and methyl iodide (6 ml.) was left together for 24 hr., solid separating after 15 min. Ether was added and the solid collected [1.5 g.; m. p. 137—139° (decomp.)]. Several crystallisations from ethanol-ether gave needles, m. p. 139—142° (decomp.) of dimethyl-4-methylbenzylsulphonium iodide which could not be obtained analytically pure. On treatment with aqueous sodium picrate, a picrate was obtained; it formed yellow prisms (from ethanol), m. p. 115°, not depressed on admixture with authentic dimethyl-4-methylbenzylsulphonium picrate. The crude iodide (0.5 g.), ethanol (15 ml.), water (3 ml.), and silver bromide (4 g.) were shaken at 20° for 1½ hr., then filtered, and the filtrate was evaporated to a syrup which solidified. Crystallisation from methanol-ether gave needles of dimethyl-4-methylbenzylsulphonium bromide, m. p. and mixed m. p. 109—110° (0.31 g.). (b) The sulphide (0.5 g.), nitromethane (3 ml.), and methyl bromide (2 ml.) were left together for 3 days. The solid was collected and crystallised from ethanol, to give trimethylsulphonium bromide (0.33 g.), m. p. 195—200° (decomp.) (Found: C, 23.1; H, 5.9. Calc. for C₃H₉BrS: C, 22.9; H, 5.8%). Blattner²² gives m. p. 185—189° (decomp.).

Reaction of Crude Dimethyl-4-methylbenzylsulphonium Iodide with Methyl Iodide.—The crude sulphonium iodide (0.5 g.; m. p. 137—139°), methyl iodide (5 ml.), and ethanol (10 ml.) were left for 6 days, giving trimethylsulphonium iodide (0.22 g.) as needles, m. p. 209—211° (decomp.). Evaporation of the mother-liquors gave a lachrymatory oil.

Reactions of 4-Chlorobenzyl Methyl Sulphide.—(a) Methyl iodide (6 ml.) and the sulphide (1.0 g.) were left together for 24 hr., solid separated (1.24 g.; m. p. 164—168°). Crystallisation from ethanol afforded trimethylsulphonium iodide (0.41 g.), m. p. 207—210° (decomp.), and material, m. p. 137—167° (0.62 g.), which could not be further purified. The latter with aqueous sodium picrate gave 4-chlorobenzyl dimethylsulphonium picrate, prisms (from ethanol), m. p. 147—148° (Found: C, 43.7; H, 3.6. C₁₅H₁₄ClN₃O₂S requires C, 43.3; H, 3.4%). (b) The sulphide (0.5 g.), methyl bromide (2.0 ml.), and nitromethane (3 ml.) were left for 17 hr. Addition of ether and crystallisation of the product from ethanol gave trimethylsulphonium bromide (0.41 g.), m. p. 195—198° (decomp.). Evaporation of the mother-liquors gave an oil (1.0 g.) which when heated with thiourea (0.37 g.) in ethanol gave S-4-chlorobenzylthiouronium bromide (1.23 g.), m. p. and mixed m. p. 195—196°.

Reaction of Methyl 1-Naphthylmethyl Sulphide with Methyl Iodide.—Methyl iodide (1.0 ml.), the sulphide (1.0 g.), and acetone (5 ml.) were left overnight, and the solid was collected (1.25 g.; m. p. 123—126°). Fractional crystallisation from ethanol-acetone afforded trimethylsulphonium iodide (0.22 g.) and dimethyl-1-naphthylmethylsulphonium iodide (0.29 g.) as plates, m. p. 117—119° (decomp.) (Found: C, 47.3; H, 4.6. C₁₃H₁₅IS requires C, 47.2; H, 4.6%). Evaporation of the mother-liquors and crystallisation of the residual solid from light petroleum (b. p. 60—80°) gave 1-iodomethylnaphthalene (0.15 g.), m. p. 58—60°.

Quantitative Experiments.—The sulphide (0.3 g.) and the required amount of methyl iodide (1, 3, 5, 10, or 20 mol.) were left at 18—20° for 4, 24, or 72 hr. Ether was added and the solids were collected and weighed, and their melting points were determined. The sulphides used were benzyl-, 4-methylbenzyl-, 4-chlorobenzyl-, and 4-methoxybenzyl-methyl sulphide. The results are given in the introductory section.

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²² Blattner, *Monatsh.*, 1919, **40**, 420.